XX. *Observations and Experiments, made with a view to ascertain the Means by which the Spiders that produce Gossamer effect their aërial Excursions. By John Blackwall, Esq., F.L.S.*

Read June 5, 1827.

Although it is well known that spiders sometimes ascend into the atmosphere through the instrumentality of fine lines of a viscous gummy matter, which proceed from the papillæ situated at the extremity of the abdomen, yet the manner in which these aërial journeys are effected still remains involved in obscurity, and considerable diversity of opinion exists as to the particular species of spider by which they are undertaken. This deficiency leaves open a wide field for speculation; and accordingly we find, that natural historians have ascribed this interesting occurrence to several distinct causes,—such as the agency of winds, evaporation, and electricity; the exercise of peculiar physical powers, with which the spiders that produce gossamer have been supposed to be endowed; and the extreme levity of the webs of these insects, which are represented by some writers on the subject to be of less specific gravity than atmospheric air*: but that each of these hypotheses is unfounded, and in direct oppo-

* For a concise statement of the principal circumstances which have given rise to the above conjectures, and for references to the sources from which they are derived, see the *Introduction to Entomology* by Kirby and Spence, Letter xxiii.

sition to facts, will be rendered evident by the following observations and experiments, from which a satisfactory solution of the difficulty, it is hoped, will be obtained.

That gossamer, which usually abounds most in the months of September and October, is perceived to ascend into the atmosphere only in serene bright weather, is, I believe, generally allowed: it is also admitted, that gossamer in the air is invariably preceded by gossamer on the ground. These, as will appear in the sequel, are circumstances of much importance in the present investigation; every method of accounting for the ascent of the webs and spiders, however plausible, which does not imply their concurrence, being necessarily erroneous.

But to proceed to my own researches:—A little before noon on the 1st of October 1826, which was a remarkably calm sunny day, the thermometer in the shade ranging from 55°·5 to 64°, I observed that the fields and hedges in the neighbourhood of Manchester were covered over, by the united labours of an immense multitude of spiders, with a profusion of fine shining lines, intersecting one another at every angle, and forming a confused kind of net-work. So extremely numerous were these slender filaments, that in walking across a small pasture my feet and ankles were thickly coated with them: it was evident, however, notwithstanding their great abundance, that they must have been produced in a very short space of time, as early in the morning they were not sufficiently conspicuous to attract my notice; and on the 30th of September they could not have existed at all; for on referring to my meteorological journal, I find that a strong gale from the south prevailed during the greater part of that day.

A circumstance so extraordinary could not fail to excite curiosity; but what more particularly arrested my attention was the ascent of an amazing quantity of webs of an irregular complicated

complicated structure, resembling ravelled silk of the finest quality and clearest white. They were of various shapes and dimensions, some of the largest measuring upward of a yard in length, and several inches in breadth in the widest part; while others were almost as broad as long, presenting an area of a few square inches only.

These webs, it was quickly perceived, were not formed in the air, as is generally believed, but at the earth's surface. The lines of which they were composed being brought into contact by the mechanical action of gentle airs, adhered together, till by continual additions they were accumulated into flakes or masses of considerable magnitude, on which the ascending current, occasioned by the rarefaction of the air contiguous to the heated ground, acted with so much force as to separate them from the objects to which they were attached, raising them in the atmosphere to a perpendicular height of at least several hundred feet. I collected a number of these webs about mid-day as they rose, and again in the afternoon, when the upward current had ceased and they were falling, but scarcely one in twenty contained a spider; though on minute inspection I found small winged insects, chiefly aphides, entangled in most of them.

From contemplating this unusual display of gossamer, my thoughts were naturally directed to the animals which produced it; and the countless myriads in which they swarmed almost created as much surprise as the singular occupation that engrossed them. Apparently actuated by the same impulse, all were intent upon traversing the regions of air; accordingly, after gaining the summits of various objects, as blades of grass, stubble, rails, gates, &c., by the slow and laborious process of climbing, they raised themselves still higher by straightening their limbs; and elevating the abdomen, by bringing it from the

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usual horizontal position into one almost perpendicular, they emitted from their spinning-apparatus a small quantity of the glutinous secretion with which they construct their webs. This viscous substance being drawn out by the ascending current of rarefied air into fine lines several feet in length, was carried upward, until the spiders feeling themselves acted upon with sufficient force in that direction, quitted their hold of the objects on which they stood, and commenced their journey by mounting aloft.

Whenever the lines became inadequate to the purpose for which they were intended, by adhering to any fixed body, they were immediately detached from the spinners, and so converted into terrestrial gossamer by means of the last pair of legs, and the proceedings just described were repeated; which plainly proves that these operations result from a strong desire felt by the insects to effect an ascent. But what, it may be asked, is the exciting cause of this singular propensity? It has been suggested that hunger, or an inclination to procure some favourite kind of food, may supply the requisite stimulus. These suppositions, however, are discountenanced by the plump appearance which the animals exhibit; by their total disregard of such winged insects as happen to be placed within their power; by their utter inability to regulate their motions, while afloat, in any other manner than by letting out or drawing in the lines by which they are conveyed through the air, and thus promoting their ascent or descent; by the unsuitableness of the lines for securing their prey; and lastly, by the uncertainty when a favourable day for their purpose may occur, or even that one may occur at all.

Were I to hazard a conjecture on the subject, I should be disposed to attribute the manifest anxiety of these insects to change

change their quarters, to a feeling of insecurity occasioned by their proximity to one another;—the prodigious numbers which in favourable seasons are usually congregated together affording the more powerful individuals an opportunity, seldom neglected by these voracious creatures, of making an easy prey of the weaker: and this opinion is strengthened, if not confirmed, by the fact, that they are chiefly animals which have not arrived at maturity that undertake these migrations.

I have asserted, that when the spiders which produce gossamer perform their aërial journeys, they are borne upward by an ascending current of rarefied air acting on the slender lines which proceed from their spinners. I shall now endeavour to prove that this curious atmospherical phænomenon, which well deserves the attention of meteorologists, affords them the only available means of accomplishing their object; and that the hypotheses previously adverted to are quite irreconcileable with facts, and consequently must be erroneous.

It has been already stated, that gossamer is never seen floating in the air except in calm sunny weather; its buoyancy, therefore, evidently does not depend upon the agency of winds, usually so called: indeed it is probable that winds never do take an upward direction, unless influenced by some extraordinary circumstance or local peculiarity; the ascent of gossamer, on the contrary, is frequently observed to take place over a great extent of country on the same day. It was noticed on the 1st of October, for example, in England, Wales, and Ireland.

If a satisfactory explanation of this interesting fact cannot be derived from the operation of winds, it is still less likely to be deduced from the action of evaporation or electricity; for, not to insist upon the probable, I had almost said absolute, insufficiency of these powers considered as agents, experiments show that the spiders do not select those periods for making an ascent when

when the evaporating force is unusually great, or the electricity of the atmosphere is remarkable for its intensity*.

But though each of the alleged causes just adverted to appears incompetent to produce the required effect, yet one abundantly adequate may perhaps be found in the physical endowments of the animals themselves, or in the extreme lightness of their webs: these two last-named suppositions therefore merit a careful examination.

If the spiders do impel their lines upward by the voluntary exercise of some animal function which has hitherto eluded the researches of physiologists, it follows, that when the communication is interrupted, the lines, unless influenced by some other force, must necessarily fall. Now the reverse of this uniformly ensues: for if the insects, after having commenced their ascent, are suddenly separated from the lines to which they are attached, the latter still continue to ascend, their motion being accelerated by their diminished gravity, but the former are rapidly precipitated to the ground. The conclusion is obvious. The buoyancy of the lines cannot be occasioned by the beings which produce them; and the ascent of large flakes of web unoccupied by spiders, before alluded to, confirms this opinion.

Perhaps the buoyancy of lines from which spiders have been detached, and of webs altogether destitute of these insects, may be regarded as facts powerfully contributing to establish the idea that this animal secretion is specifically lighter than the mixed gases which compose the atmosphere. The fallacy of this notion, however, is easily proved by experiment. In the

* The evaporating force may be determined by the atmometer, or from the temperature at which the aqueous vapour in the atmosphere begins to be condensed into water, and the temperature of the air. See the first series of the *Memoirs of the Literary and Philosophical Society of Manchester*, vol. v. part ii. p. 588. The electrical state of the atmosphere is shown by Bennet's gold-leaf electrometer.

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comparatively still air of a room without fire, both the lines and webs descend slowly to the floor, the latter falling with the greater degree of velocity.

Were these productions lighter than atmospheric air, or were the spiders capable of effecting an ascent without the help of adventitious aid, a calm though cloudy day might answer their purpose; but as considerable warmth is required to produce an ascending current of rarefied air strong enough to bear them from the earth, a bright as well as still day is indispensable.

Founded on results obtained from an experiment which has been frequently made, but never conducted with sufficient care, is the belief entertained by many eminent entomologists that spiders can forcibly propel or dart out threads from their papillæ. Now as this process would, contrary to my own experience, imply the exercise of a physical power peculiar to these creatures; and as attempts have been made to explain on this principle the fabrication of their webs in situations where their ordinary mode of proceeding could not be employed, I determined to repeat the experiment from which so strange a conclusion has been deduced. With this view, having procured a small branched twig, I fixed it upright in an earthen vessel containing water, its base being immersed in the liquid, and upon it I placed several of the spiders which produce gossamer. Whenever the insects thus circumstanced were exposed to a current of air, either naturally or artificially produced, they directly turned the thorax towards the quarter whence it came, even when it was so slight as scarcely to be perceptible, and elevating the abdomen, they emitted from their spinners a small portion of glutinous matter, which was instantly carried out in a line, consisting of four finer ones, with a velocity equal, or nearly so, to that with which the air moved, as was apparent from observations made on the motion of detached lines similarly exposed. The spiders, in the

next place, carefully ascertained whether their lines had become firmly attached to any object or not, by pulling at them with the first pair of legs; and if the result was satisfactory, after tightening them sufficiently they made them fast to the twig; then discharging from their spinners, which they applied to the spot where they stood, a little more of their liquid gum, and committing themselves to these bridges of their own constructing, they passed over them in safety, drawing a second line after them as a security in case the first gave way, and so effected their escape.

Such was invariably the result when the spiders were placed where the air was liable to be sensibly agitated: I resolved therefore to put a bell-glass over them; and in this situation they remained seventeen days, evidently unable to produce a single line by which they could quit the branch they occupied without encountering the water at its base; though on the removal of the glass they regained their liberty with as much celerity as in the instances already recorded.

This experiment, which from a want of due precaution in its management has misled so many distinguished naturalists, I have tried with several of the geometric spiders, and always with the same success. Placed under the bell-glass, or in any close vessel, they in vain endeavoured to make their escape from the branch to which they were confined; but in the disturbed air of an inhabited room they readily accomplished their object.

Instances of long-sustained abstinence from food by insects of the genus *Aranea*, unaccompanied by any manifest diminution of vital energy, have been given by various observers. In adding another case to the list it is proper to remark, that it must be received solely on my own authority.

Some of the spiders which produce gossamer were procured on

on the 2nd of October, and inclosed in glass phials with ground stoppers, where they were suffered to remain till the 16th of December, an interval of seventy-five days, without either food or moisture; yet at the expiration of that period, the only alterations perceptible in their external condition were a small decrease in bulk, and a slightly wrinkled appearance, particularly of the abdomen: but their functions were seemingly unimpaired; for on warm days, or when excited by artificial heat, they were lively in their motions, and to the last continued to produce their threads, which were often destroyed for the purpose of ascertaining whether they would be replaced by others with apparently the same facility as at the time of their capture.

It is particularly deserving of notice, that these insects, though unable to climb up the smooth perpendicular sides of the phials on their first introduction, soon contrived to traverse the interior of their prisons in every direction.

In order to illustrate their manner of proceeding on this occasion, the case of an individual has been selected for description,—the same method, with a few trivial modifications, being pursued by all. Elevating the abdomen, and pressing the spinning-apparatus against the side of the phial, this spider emitted from its papillæ a little viscous fluid, which on exposure to the air hardened into a minute semi-transparent speck; then moving to a short distance, and drawing out a thread after it, one end of which remained fixed to the spot it had just quitted, it connected this filament with another part of the phial by applying the spinners as before. Several lines being thus produced, the spider speedily raising itself upon them above the bottom of the phial, promoted its undertaking by repeating the process just described; every step so gained enabling it to carry its operations still higher.

From the cylindrical figure of the phial, it follows that all the lines attached to its sides by their extremities, such as were vertical alone excepted, formed with those sides chords to arcs of various magnitudes. Lowering itself from one of these chords to another, and applying the spinners to each in succession, the spider soon connected the whole of them together by a line; then ascending again to the greatest altitude it could attain, and dropping down by a thread to the bottom of the phial, over which it walked to the opposite side; it there drew the thread tight and made it fast, having prevented it from coming in contact with the glass previously by raising the abdomen a little. To this oblique line it united others, extending them in different directions, till by these means it established a communication with every part of the phial. As there was some difficulty in tracing these operations with the unassisted eye, lenses of the magnifying powers of six and eight were employed.

The spiders seen ascending into the atmosphere on the 1st of October were of two distinct species; but as the technical difference of insects has engaged only a small share of my attention, I shall leave the task of identifying them to those who are more familiar than myself with this branch of entomology. The subjoined remarks on some of the characteristics of these insects, which are more conveniently illustrated by the pen than the pencil, may serve to facilitate this object.

One species has four of its eight eyes much larger than the other four. Two pair situated in the front or fore-part of the head are arranged thus ˙..˙, the relative size of the dots being nearly the same as that of the eyes. The other pair of small ones is placed in the upper part of the head, and on each side of it one of the remaining pair of large eyes is seated. This spider has the abdomen rather depressed; the anterior limbs, which it raises in a menacing manner when any thing approaches it, are longer

longer than the posterior ones; and it moves in a lateral direction with almost as much ease and expedition as it does straight forward. The largest individuals of this species observed to be conveyed through the atmosphere by a current of air acting upon their lines, measured $\frac{1}{6}$th of an inch between the extreme points of the head and abdomen; $\frac{1}{10}$th of an inch across the broadest part of the abdomen; and weighed about a quarter of a grain.

The second species has also four eyes of a greater magnitude than the other four. The arrangement and relative size of three pair placed in the fore-part of the head may be thus expressed by dots :..: ; one of the other pair of large eyes being situated on each side of the head. Spiders of this species have the last pair of legs longer than the first, and move with great celerity, but rarely in a lateral direction. They vary considerably in colour, some being of a much darker hue than others, and these are frequently without the pale longitudinal line which extends the whole length of the thorax, and sometimes even on to the abdomen of the lighter-coloured specimens. The largest individuals seen floating in the air were somewhat inferior in weight and dimensions to the largest of the preceding species observed under similar circumstances*.

* Is this the *Aranea dorsalis* of the *Systema Naturæ*, Gmelin's edit.?

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